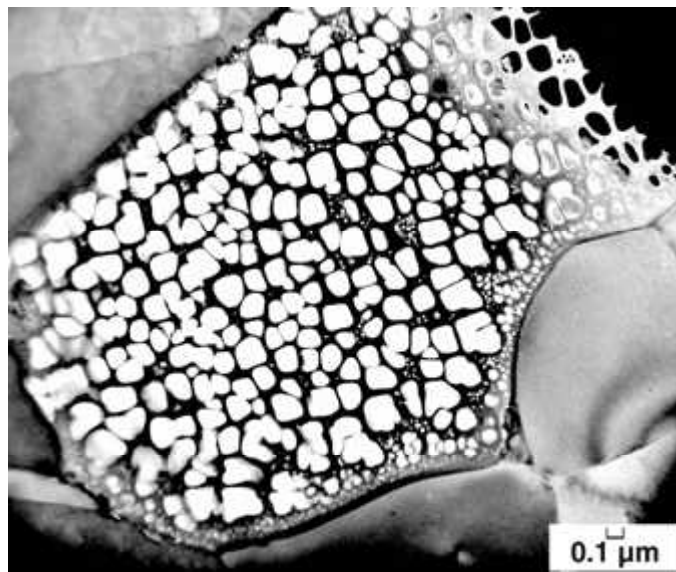


Strengthening Precipitate Morphologies Fully Quantified in Advanced Disk Superalloys

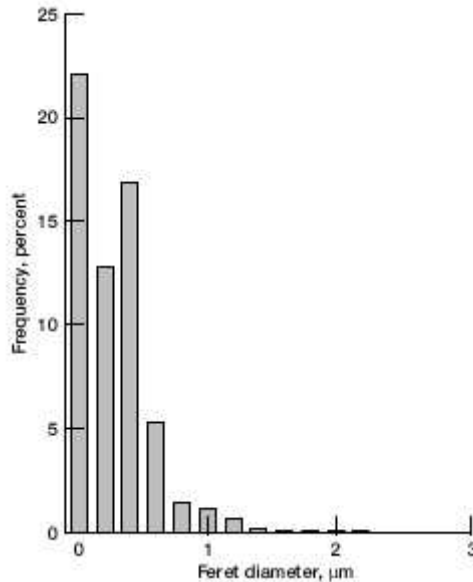
Advanced aviation gas turbine engines will require disk superalloys that can operate at higher temperatures and stresses than current conditions. Such applications will be limited by the tensile, creep, and fatigue mechanical properties of these alloys. These mechanical properties vary with the size, shape, and quantity of the γ' precipitates that strengthen disk superalloys. It is therefore important to quantify these precipitate parameters and relate them to mechanical properties to improve disk superalloys. Favorable precipitate morphologies and practical processing approaches to achieve them can then be determined. A methodology has been developed at the NASA Lewis Research Center to allow the comprehensive quantification of the size, shape, and quantity of all types of γ' precipitates.



Disk superalloy showing various sizes of γ' precipitates.

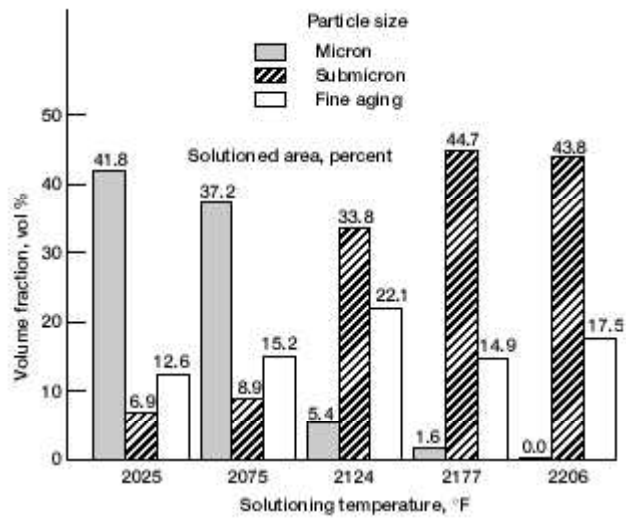
Disk superalloys can contain micrometer, submicrometer, and fine aging γ' precipitates, as in the preceding photo. Micrometer-size γ' precipitates with a diameter greater than 1 μm can survive from the original solidification structure ("primary γ' ") or grow during low-temperature solution heat treatments. These precipitates were observed by optical and scanning electron microscopy of metallographically mounted, polished, and etched sections. Submicrometer-size γ' precipitates between 0.1 and 1 μm in diameter often form during quenching from solution heat treatments. These precipitates often grow with their edges approximately aligned along preferred crystallographic planes to produce regularly aligned rounded cubes or connected rectangles. In general, transmission electron microscopy (TEM) of thin foils obtained consistently oriented, high-resolution images of the aligned morphology. Fine aging γ' precipitates less than 0.1 μm in diameter formed

later during solution quenching and subsequent lower temperature heat treatments. These very small, nearly spherical precipitates also had to be imaged by transmission electron microscopy to be accurately quantified.



Size distribution of γ' precipitates in a disk alloy specimen that was first solution heat treated at 2124 °F.

The delicate balance between superior disk mechanical properties and practical processing approaches requires unprecedented levels of γ' microstructural quantification. Therefore, SigmaScan image analysis software was used to determine the size, shape, and volume fraction of each type of γ' precipitate. A typical measured distribution of γ' feret diameter versus frequency is shown in the preceding bar graph for a disk alloy specimen solution heat treated at 2124 °F for 1 hr and cooled in the furnace, then subsequently heat treated at 1550 °F for 2 hr and at 1400 °F for 8 hr. Micrometer, submicrometer, and fine aging γ' precipitates were present in this specimen's microstructure. The volume fractions of micrometer, submicrometer, and fine aging γ' precipitates for specimens of the same disk alloy solution heat treated from 2025 to 2206 °F are compared in the following figure. Increasing the solution heat treatment temperature reduced micrometer γ' content and increased submicrometer γ' content. These changes can affect the strength and creep resistance of this disk alloy. The accurate quantification of γ' morphology and associated mechanical properties for different disk alloy microstructures can enable modeling of processing-microstructure-property relationships in advanced disk alloys. This can aid in obtaining improved mechanical properties in advanced disk alloys by using practical processing to achieve favorable γ' morphologies.



g' volume fractions of heat-treated disk alloy specimens.

Lewis contacts: Dr. Timothy P. Gabb, (216) 433-3272, Timothy.P.Gabb@grc.nasa.gov;
 Dr. John Gayda, (216) 433-3273, John.Gayda@grc.nasa.gov; David L. Ellis, (216) 433-
 8736, David.L.Ellis@grc.nasa.gov; and Dr. Anita Garg, (216) 433-8908,
 Anita.Garg@grc.nasa.gov

Author: Dr. Timothy P. Gabb

Headquarters program office: OASTT

Programs/Projects: Propulsion Systems R&T, AST, EPM, P&PM, HITEMP